SOLAR THERMAL UTILIZATION
PAST PRESENT AND FUTURE

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WHY SOLAR ?

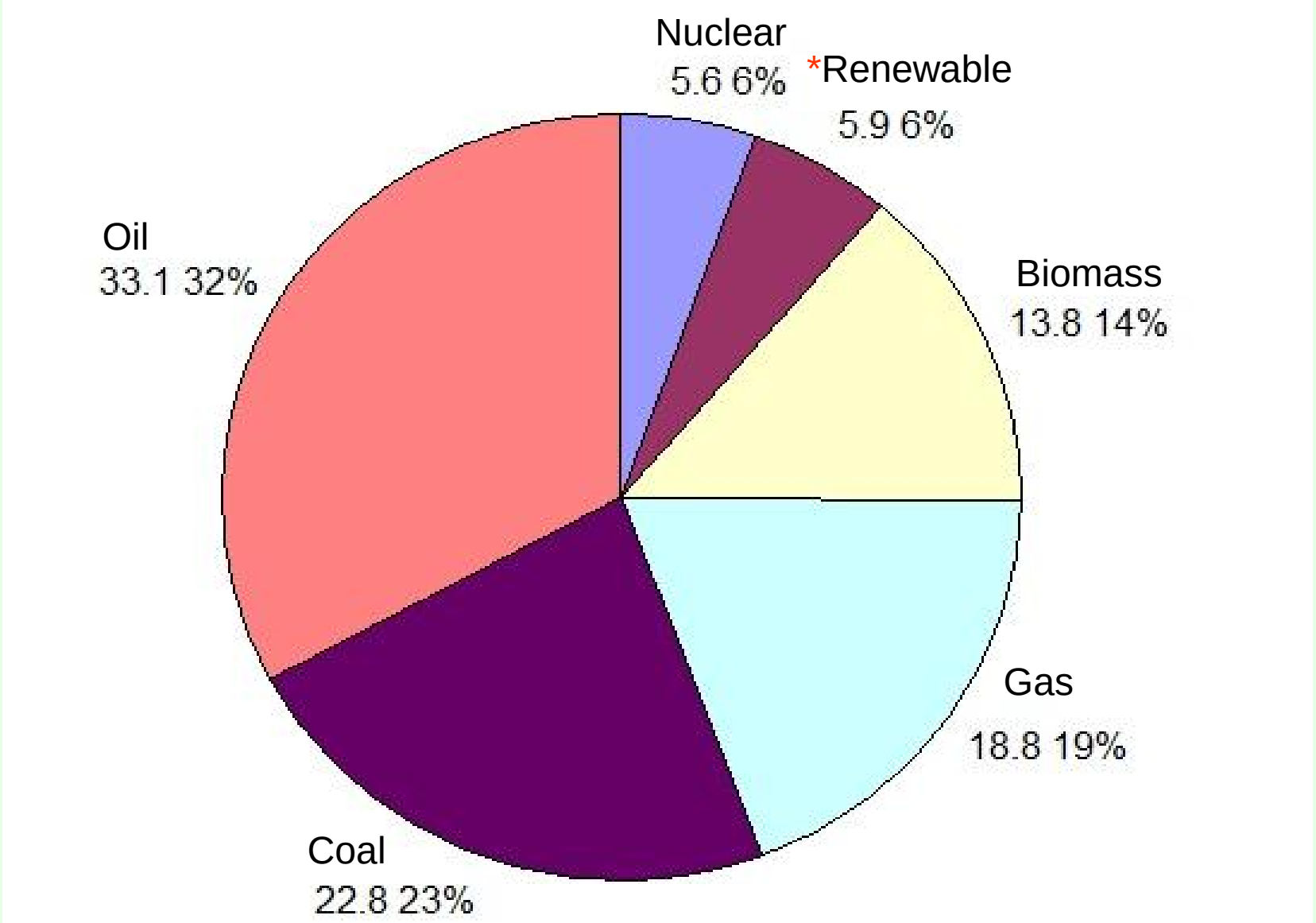
OUR RESPONSIBILITIES – TO PROTECT THE EARTH FOR FUTURE GENERATION

WHY SOLAR ? WHY NOW ?

- GLOBAL WARMING
- ENERGY INDEPENDENCE
- ENERGY SECURITY
- ELECTRICITY PRICES ↑
- GOVERNMENT INITIATIVES / SUPPORT

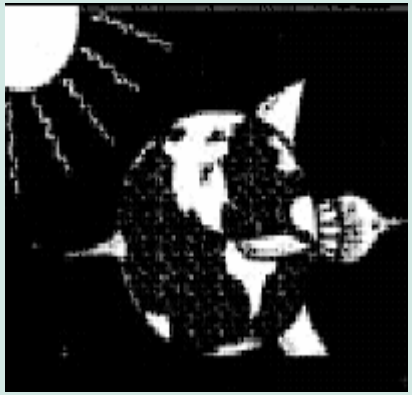
What Energy ?

Global average



é .and 80% of energy supplies come from limited resources known for environmental pollution !

Degrading Environment….



Imagine the earth to be a spaceship .

Limited supply of air, water and energy .

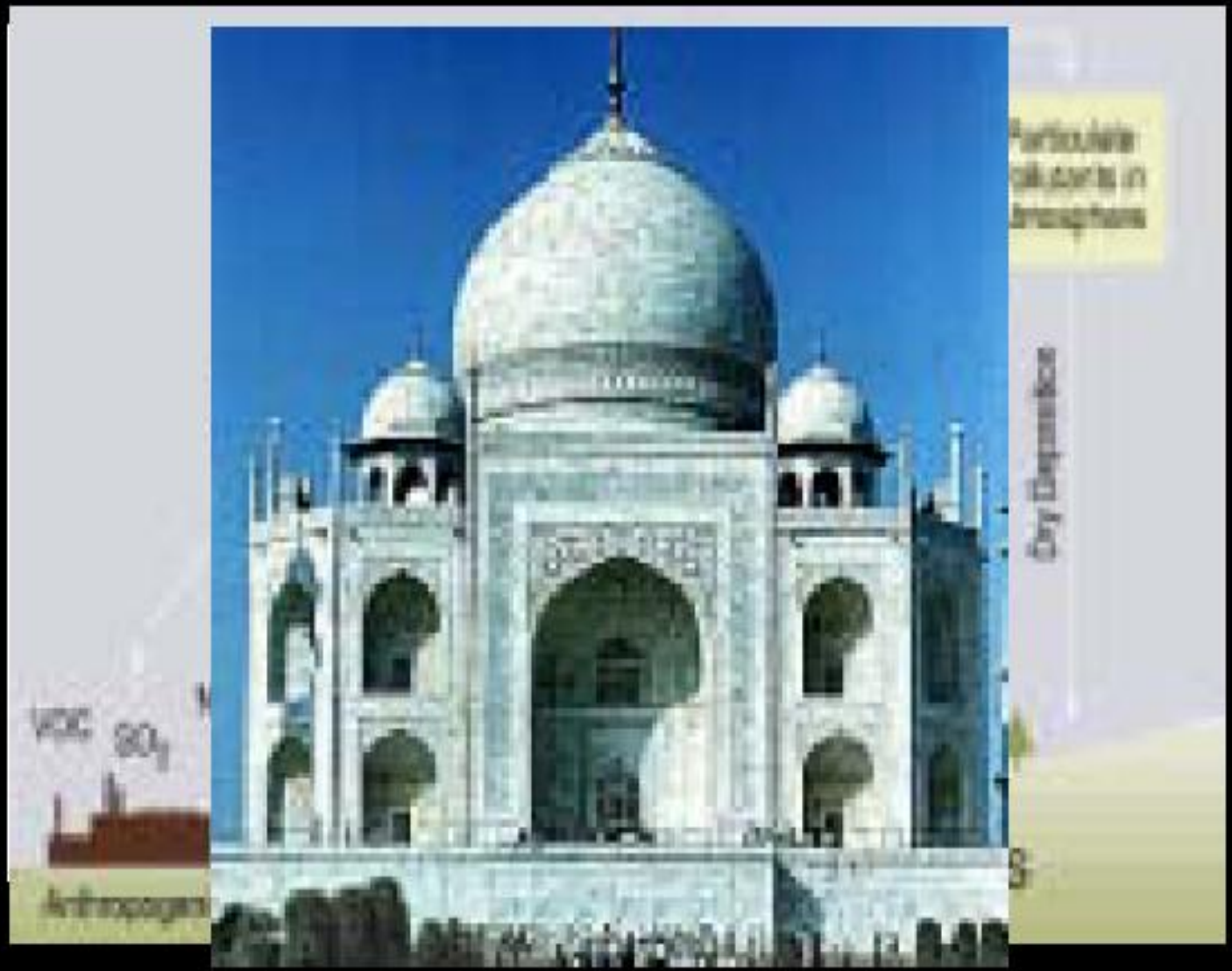
All thrash generated carried onboard .

Increase population ∞ energy demand .

Non –renewable resources to last 100 yrs. But long before that the pollution caused by use of fossil fuels will have caused a serious problem .

THE BURNING OF FOSSIL FUELS IS HAVING A LARGE IMPACT

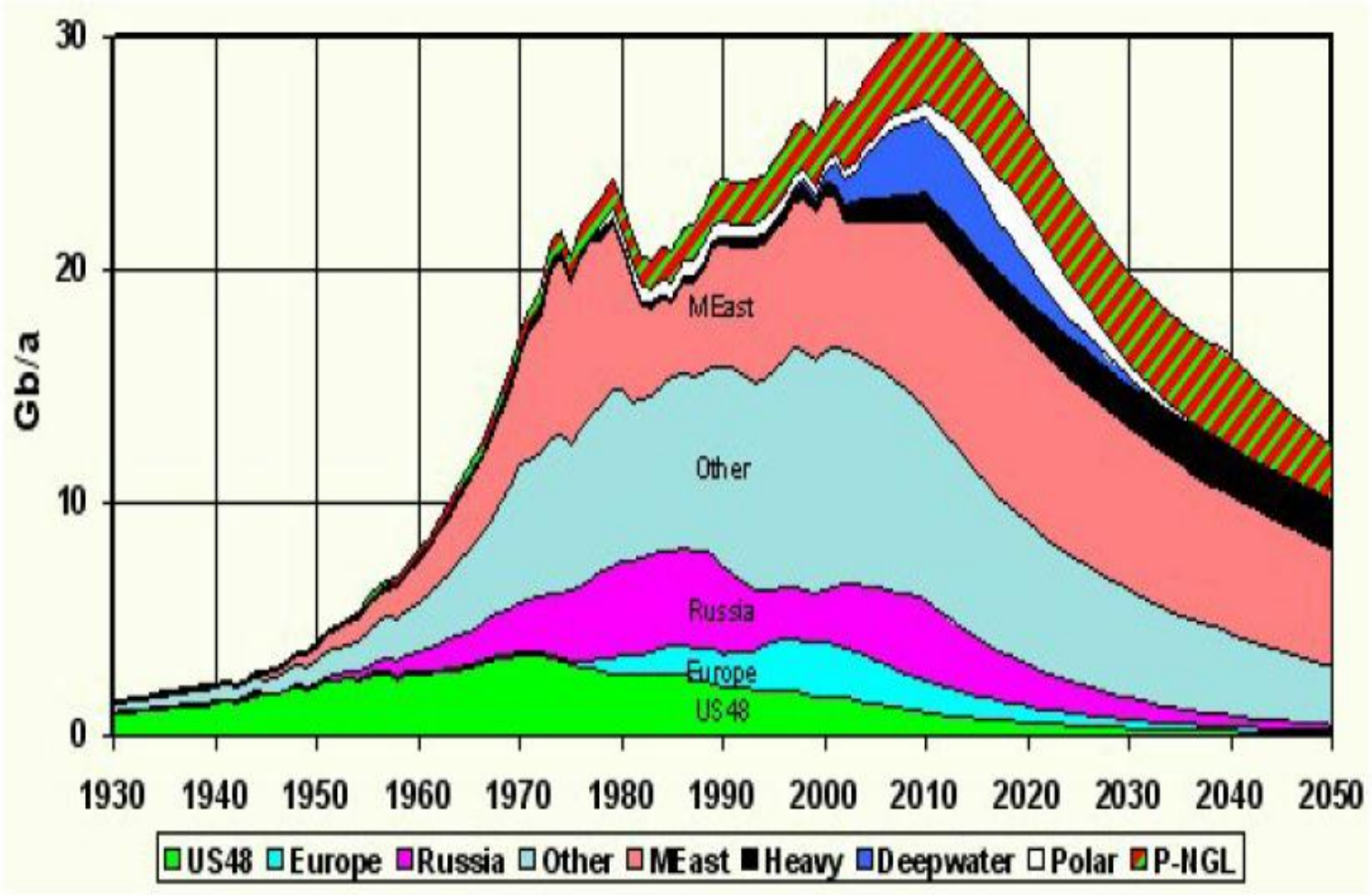
Environmental Impact ...




2005 Melt Extent
Greenland Ice Melt Acceleration
2005 Melt Extent
1992 Melt Extent
2,000m Elevation
University of Colorado CIRES
Courtesy Russell Huff and Konrad Steffen

End of an Era

100 years of exponential growth in fossil fuel use will soon be ending due to environmental and economic constraints



WHY SOLAR ?

You assume the diameter of the earth is 8000 miles and using 2240lb/ton(British ton), the 4lbs . Can be calculated using the following formula:

$$\frac{4x10^{6}x\pi x(8x10^{3})^{2}}{4x\pi x(93x10^{6)2}\ x\ 4} = 4.14lbs.$$

For every kWh of electricity generated by solar energy ,the following emissions are avoided since that kWh need not be generated from a fossil fuel power plant. In one year ,the approximate avoided emissions in lbs/year are :

SOLAR POWER PLANT SIZE	Co_2	NO_x	SO_x	PARTICULATES
1kW	2,508	6.3	5.2	0.36
10kW	25,800	63	52	3.6
100kW	258,000	630	520	36
1MW	2,580,000	6300	6200	360

Every second 657 million tons of hydrogen are converted to 653 million tons of helium in our sun . The missing 4 million tons are converted to light and heat energy via \Einstein's $E=MC^2$ equation and Radiated into space .<u>At an average distance of 93 million miles from the sun ,the earth collects approximately 4lbs.of total energy ,which supports life On earth as we know it .</u>

WHY SOLAR ?

>> In a single one hour period, the sun sends enough energy to our planet to meet all of our energy needs for an entire year.

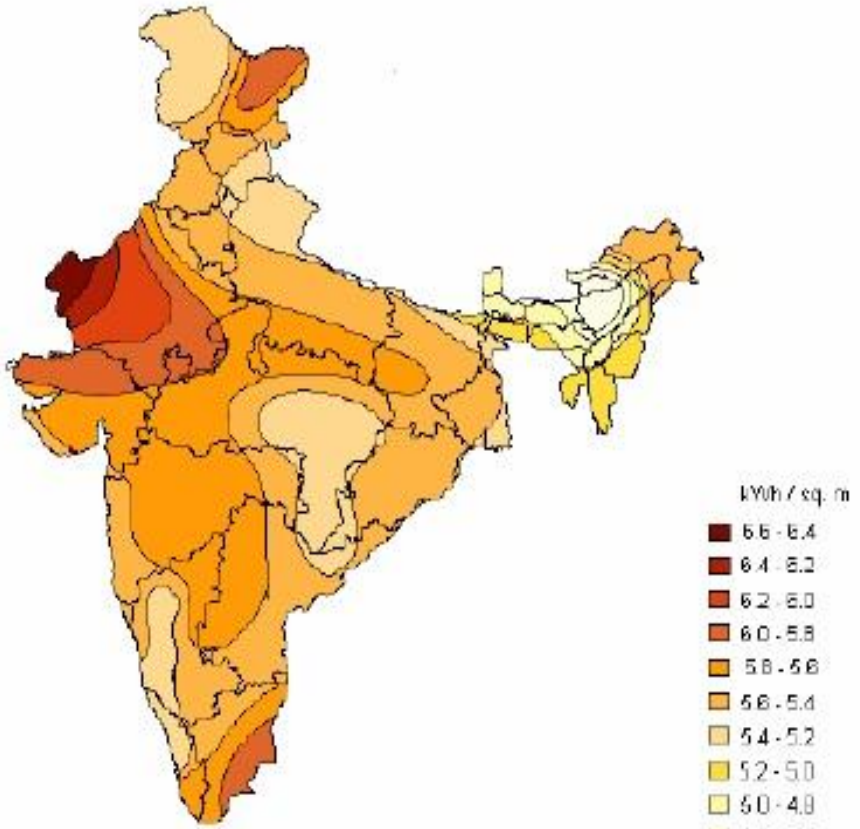
>> The availability and cost of delivering energy from the sun to our planet has remained amazingly constant for 4 billion years.

India offers huge solar market potential

Solar Radiation in India

- India receives 3000 hrs* of sunshine every year , equivalent to 5000 trillion KWH.
- Most parts in India receive 4 – 7 KWh of solar radiation per sq.meter per day with 250 - 300 sunny days in a year.

*http://www.solarindiaonline.com; The Energy and Resources Institute (TERI)



Source - Solar Energy Potential in India - TERI

" We will pool all our scientific, technical and managerial talents, with financial sources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people"
– Dr.Manmohan Singh, Prime Minister of India.

LAUNCHING OF SOLAR INDIA

JAWAHARLAL NEHRU NATIONAL SOLAR MISSION

- 20GW BY 2020
- 100GW BY 2030
- 200GW BY 2050
- 20 MILLION SQ.METER SOLAR THERMAL COLLECTORS (20GW power)
- 20 MILLION SOLAR LIGHTS

THE HINDU

Manmohan Singh launches 'Solar India'

Calls for creation of 'solar valleys' on the lines of the Silicon Valley

Prime Minister Manmohan Singh with Minister of New and Renewable Energy Farooq Abdullah at the Solar Energy Conclave 2010, in New Delhi on Monday.

Introducing SOLAR power ...

The Sun is a massive energy source of:

(Heat)

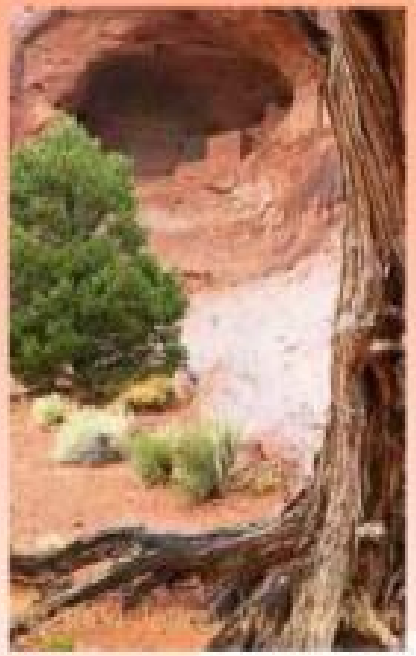
Solar THERMAL SYSTEMS

(Light)

Solar PHOTO-VOLTAIC

SOLAR THERMAL APPLICATIONS (PAST)

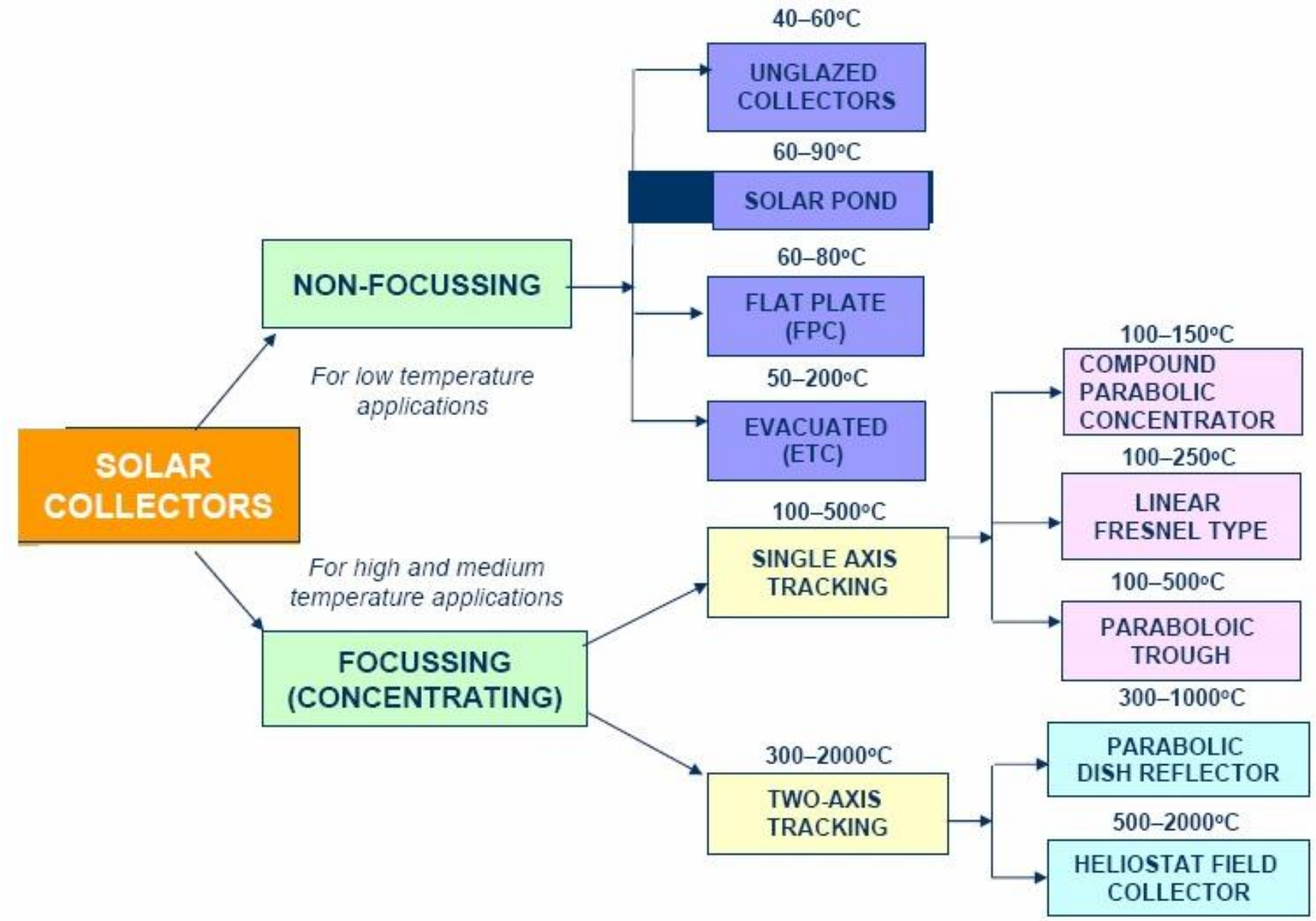
- People have been trying to harness the power of the sun for centuries.
- In 1877, air blowing over sun-heated iron was used to heat homes.
- In 1910, The first patent involving a solar collector was awarded.
- The 1930's saw the first widespread use of solar power for heating.



Solar Thermal Applications (present)

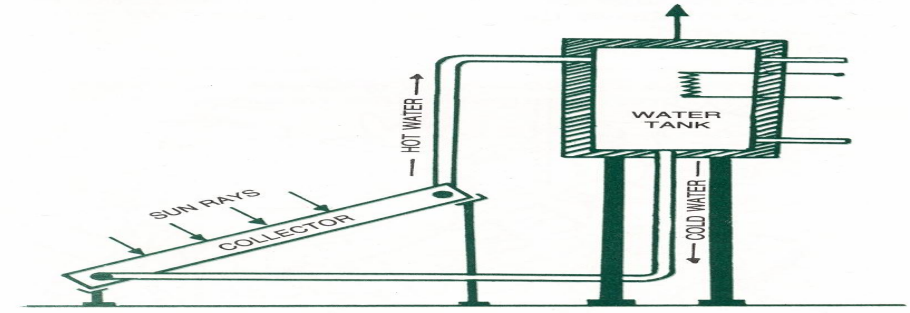
Thermal Conversion range	Applications
Low Temperature (20°C-80°C) NALSUN	Swimming pool heating Domestic hot water heating House heating Crop Drying Water Distillation
Medium Temperature (80°C-200°C) NALSUN	Rankine cycle refrigeration Absorption air conditioning Industrial drying Industrial processes Small power engine
High Temperature (>200°C) TANDEM ABSORBERS	Industrial processes Solar power plant

SOLAR ENERGY COLLECTORS



SOLAR THERMAL APPLICATIONS

SOLAR WATER HEATING



HEART OF THE SYSTEM – SELECTIVELY COATED ABSORBER

SELECTIVE ABSORBER COATINGS

1. BLACK NICKEL (POOR MOISTURE RESISTANCE)

2. BLACK CHROMIUM. (NANO COMPOSITE OF CHROMIUM AND CHROMIUM OXIDE)

DRAWBACKS OF BLACK CHROMIUM DEPOSITION

1. HIGH CURRENT DENSITY ($3A/in^2$)
2. LOW TEMPERATURE (15^0C)
3. ORGANIC ADDITIVES (STABILITY?)

ADDRESSED THE ABOVE PROBLEMS
DEVELOPMENT OF NALSUN TECHNOLOGY

ADVANTAGES OF NALSUN COATING

High absorbtivity, α < 0.95

Low emissivity, ε <0.15

Long term Thermal stability

Room temperature bath

Good covering power

Simple bath maintenance & control

Stability against atmospheric corrosion

Cost-effective coating

Easy to apply on the required substrate

Reproducibility

Good resistance against rubbing and handling

SUITABLE FOR BATCH PRODUCTION & CONTINUOUS FOIL COATING

NALSUN & ITS SOCIETAL IMPACT

TECHNOLOGY TRANSFER – 26 ENTREPRENEURS

SMALL MEDIUM AND LARGE SCALE HOT WATER

SYSTEMS – INSTALLED. (HOMES , HOSPITALS ,

HOTELS, RESORTS, CONVENTION CENTERS ,

INDUSTRIAL CANTEENS,HOSTELS ETC)

VIRTUAL POWER STATION

“A WATT SAVED IS A WATT GENERATED”

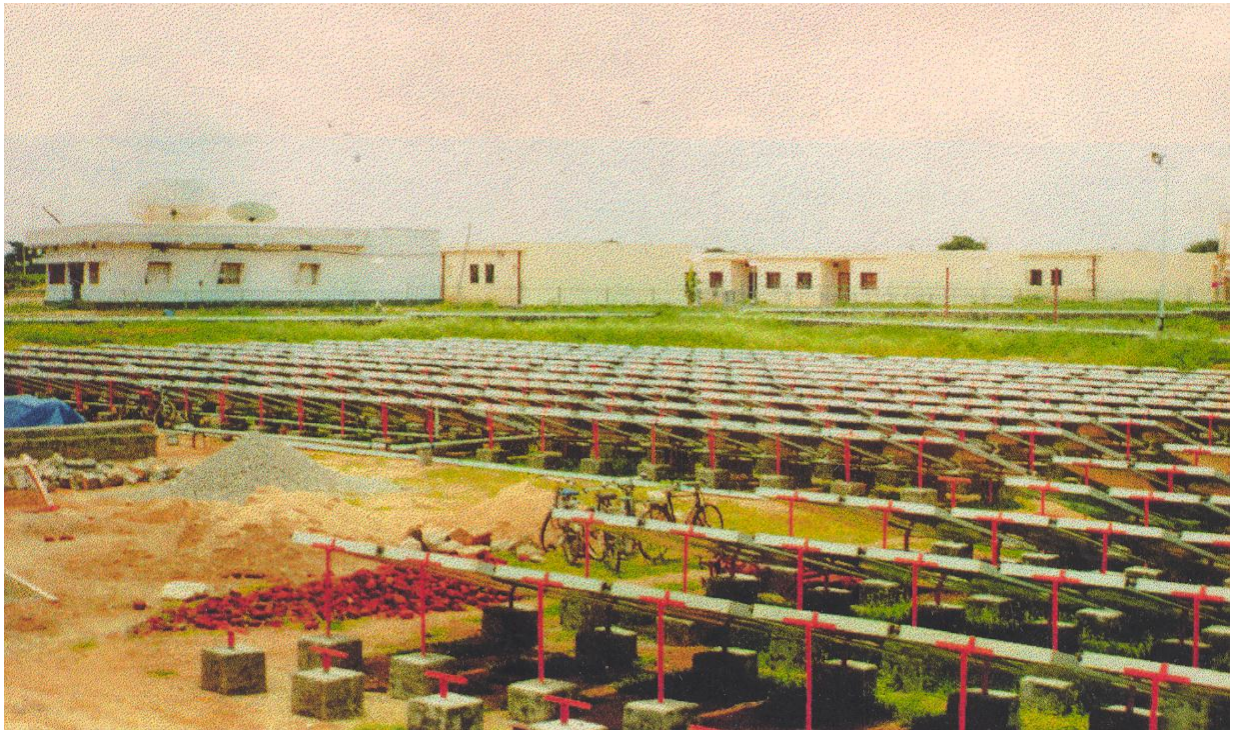
100lpd - DOMESTIC

5000lpd ï **ISKCON TEMPLE BANGALORE**

3000lpd - **DHARAMSHILA HOSPITAL**

7000lpd ï **TAJ HOTEL**

50000lpd ï **BATRA HOSPITAL DELHI**



PORTION OF THE 1.1LAKH LITERS PER DAY SOLAR WATER HEATING SYSTEMS INSTALLED AT M/S SRI VENKATESWARA HATCHERIES, VELIJULA, BY M/S SURYODAYA HITECH ENGINEERS PVT.LTD., HYDERABAD USING NALSUN COATED COLLECTORS

PORTION OF THE 1.2 LAKH LITERS PER DAY SOLAR WATER HEATING SYSTEMS INSTALLED AT M/S GODAVARI FERTILIZERS&CHEMICAL,KAKINADA BY M/S SURYODAYA HITECH ENGINEERS PVT.LTD., HYDERABAD USING NALSUN COATED COLLECTORS

Solar steam systems

A view of solar steam cooking system installed at Tirupathi, Andhra Pradesh

The system has been designed to generate over 4000 kg. of steam/day at 180 ^{0}C and 10 kg/cm^{2} which is sufficient to cook two meals for around 15,000 persons.

SOLAR STEAM GENERATION USING NALSUN (K G INDUSTRIES COAIMBATORE)

Renewable energy at a glance in India

S.No.	Source/system	Estimated potential	Achievement as on 31 August 2008
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	9041.80
2	Bio power (agro residues and plantations)	16 881	648.60
3	Bagasse cogeneration	5 000	972.83
4	Small hydro power (up to 25 MW)	15 000	2211.14
5	Energy recovery from waste (MW)	2 700	55.75
6	Solar photovoltaic power	—	2.12
	Sub total (A)	**84 776**	**12 932.24**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	95.00
8	Biomass gasifier	—	100.11
9	Energy recovery from waste	—	26.70
	Sub total (B)	**—**	**221.81**
	Total (A+B)	**—**	**13 154.05**
II	**Remote village electrification**	—	4 198 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	39.94 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MWp
	I. Solar street lighting system	—	70 474 nos
	II. Home lighting system	—	402 938 nos
	III. Solar lantern	—	670 059 nos
	IV. Solar power plants	—	2.22 MW
	v. Solar photovoltaic pumps		7148 nos
12	Solar thermal systems		
	I. Solar water heating systems	140 million m^2 collector area	2.30 million m^2 collector area
	II. Solar cookers		6.20 lakh
13	Wind pumps		1284 nos
14	Aero generator/hybrid systems		675.27 kW
IV	**Awareness programmes**		
16	Energy parks	—	504 nos
17	Akshay Urja shops	—	269 nos
21	Renewable energy clubs	—	521 nos
22	District Advisory Committees	—	560 nos

MW – megawatt; kW – kilowatt; MW_p – megawatt peak; m^2 – square metre; km^2 – kilometre square

COMMERCIALLY SUCCESSFUL –

26 ENTREPRENEURS

SOLAR WATER HEATING

Potential	Achievement
1400 Lakhs sq.m. collector area	23 lakhs sq.m collector area

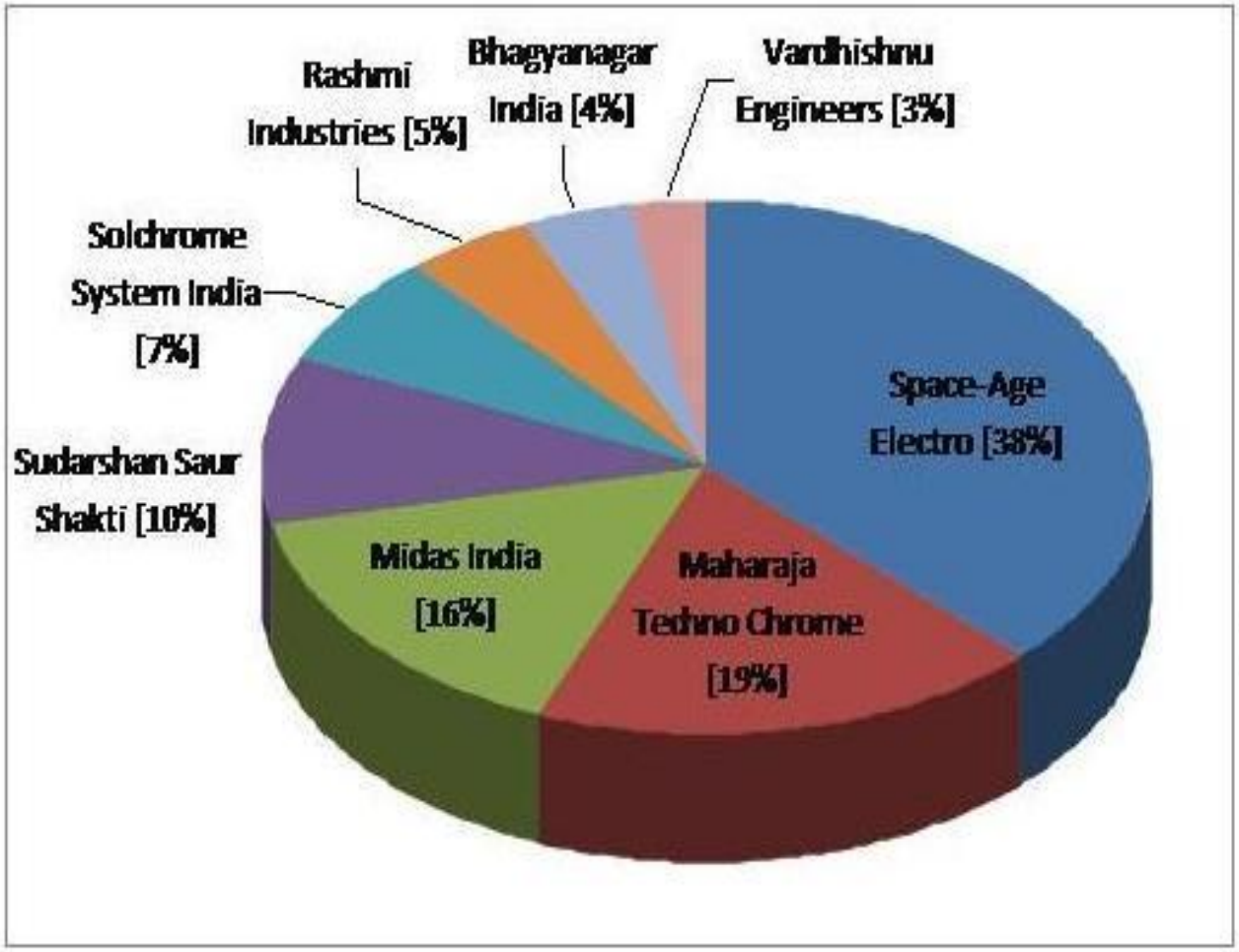
ENERGY SAVINGS

Collector area	Energy Savings
≈ 1000 sq.m	1 MW
23 lakhs sq.m	2300MW

MARKET UTILIZATION – NALSUN COATINGS – 90%

Absorber Coating: a Rising Industry in India

Submitted by **Baerbel Epp** on Wed, 07/08/2009 - 12:50.



India's coating industry has shown impressive growth rates over the last ten years. Just one manufacturer of selective coating dominated the industry a decade ago: Solchrome, who had obtained the technology from Canada. Today, 8 manufacturers are using the Nalsun technology developed by the NAL.

Jaideep Malaviya

11th May Technology Day 2010

Shri Prithviraj Chavan
Hon'ble Union Minister of State (I/C)
for Science & Technology
and Earth Sciences

Congratulations

to the scientists and technologists

of the country for their exemplary contributions that have helped the nation emerge as a technology superpower and improve the quality of lives of a billion.

Glimpses of Recent Technological Achievements & Initiatives

- Technology Mission: Winning Augmentation and Renovation for Water (WAR for Water) launched to address the problem of water scarcity in the country.
- Low Thermal Desalination Technology for one lakh litre per day and above capacity developed and stabilized.
- Nano Silver Impregnated Ceramic Drinking Water Filter developed.
- Affordable health care products, including a large number of vaccines, cellular therapies, implants and devices, and diagnostics developed and introduced.
- Nutritional foods and food supplements propagated on massive scale, including Zinc as a treatment for childhood diarrhea.
- A mega project, "Technology and Products for Solar Energy Utilization through Networking (TAP-SUN)", a CSIR led Team-India consortium, launched in partnership with MNRE.

Solar Collectors lined up at one of the NALSUN coastal installation

- 24x7 Solar Thermal Biomass Hybrid Demonstration Power Plant for Rural Electrification, ready for commercialisation.
- Oil Zapper – An eco-friendly technology developed for remediation of oily sludge and oil spills.
- Standard modulus carbon fibre technology commercialised–A 400 TPA plant using CSIR-NAL technology established.
- Fully indigenous Detonation Spray Coating (DSC) Technology commercialised.
- Several new species of ornamental high value fish ready for commercial production.

Parabolic Trough

Carbon Fibre Precision Winding Unit

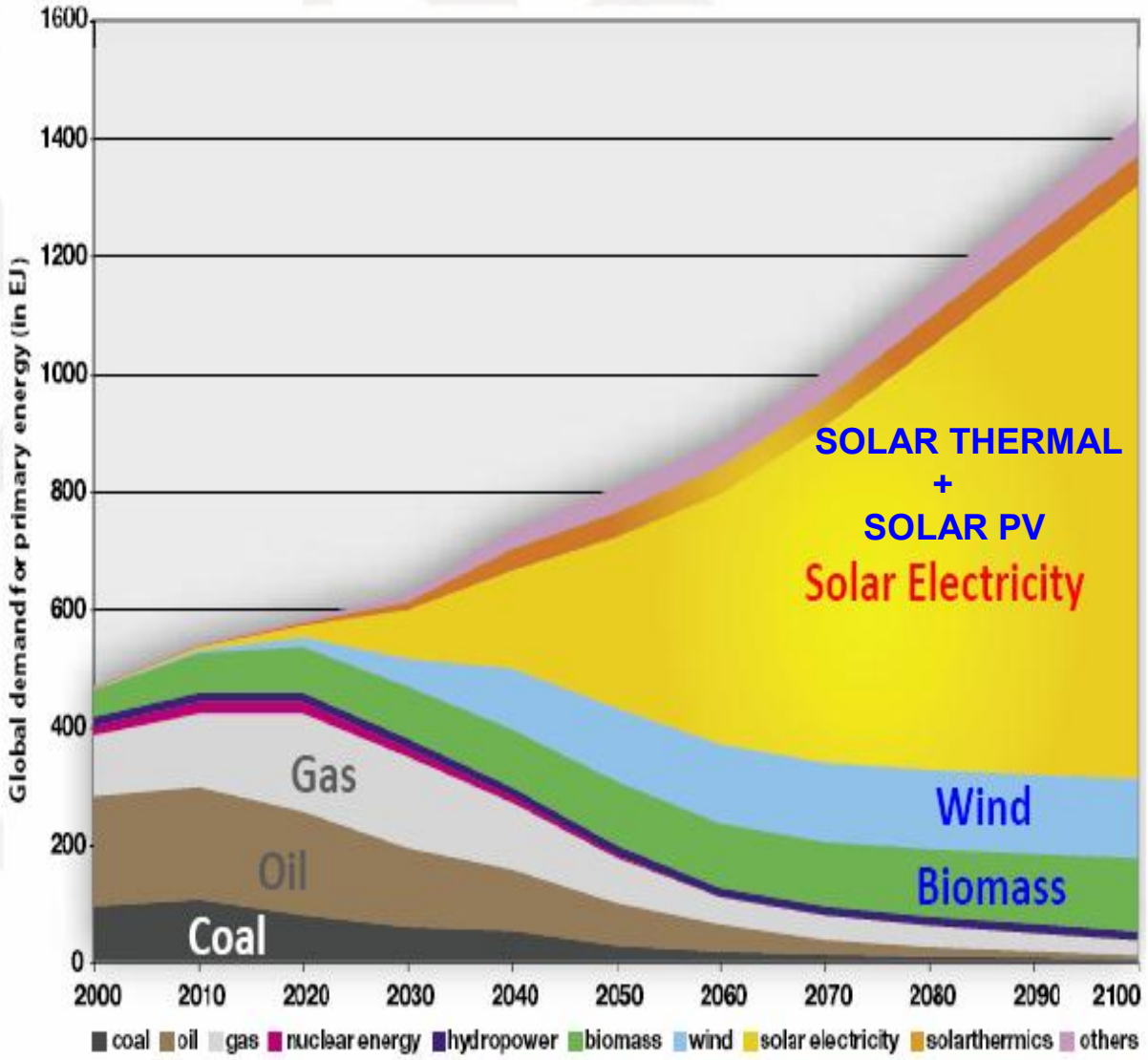
DSC Unit in operation

Ornamental Fish Culture

- CSIR awarded for the highest number of Indian patents granted (528 nos) by DIPP, Government of India.
- Special Public-Private Partnership schemes launched, including:
  - Small Business Innovation Research Initiative (SBIRI)
  - Biotechnology Industry Partnership Programme (BIPP)
  - Biotechnology Industry Research & Development Assistance Programme (BIRAP)
- To further encourage R&D across all sectors of the economy, weighted deduction on expenditure incurred on approved in-house R&D units enhanced from 150 per cent to 200 per cent.
- A national effort led by CSIR has helped government to give nod for researchers to have an equity stake in scientific enterprises and spin-offs while still being employed in their organisations.

Ministry of Science and Technology and Ministry of Earth Sciences
Government of India

Global Demand of Primary Energy



Source : the European renewable energy council

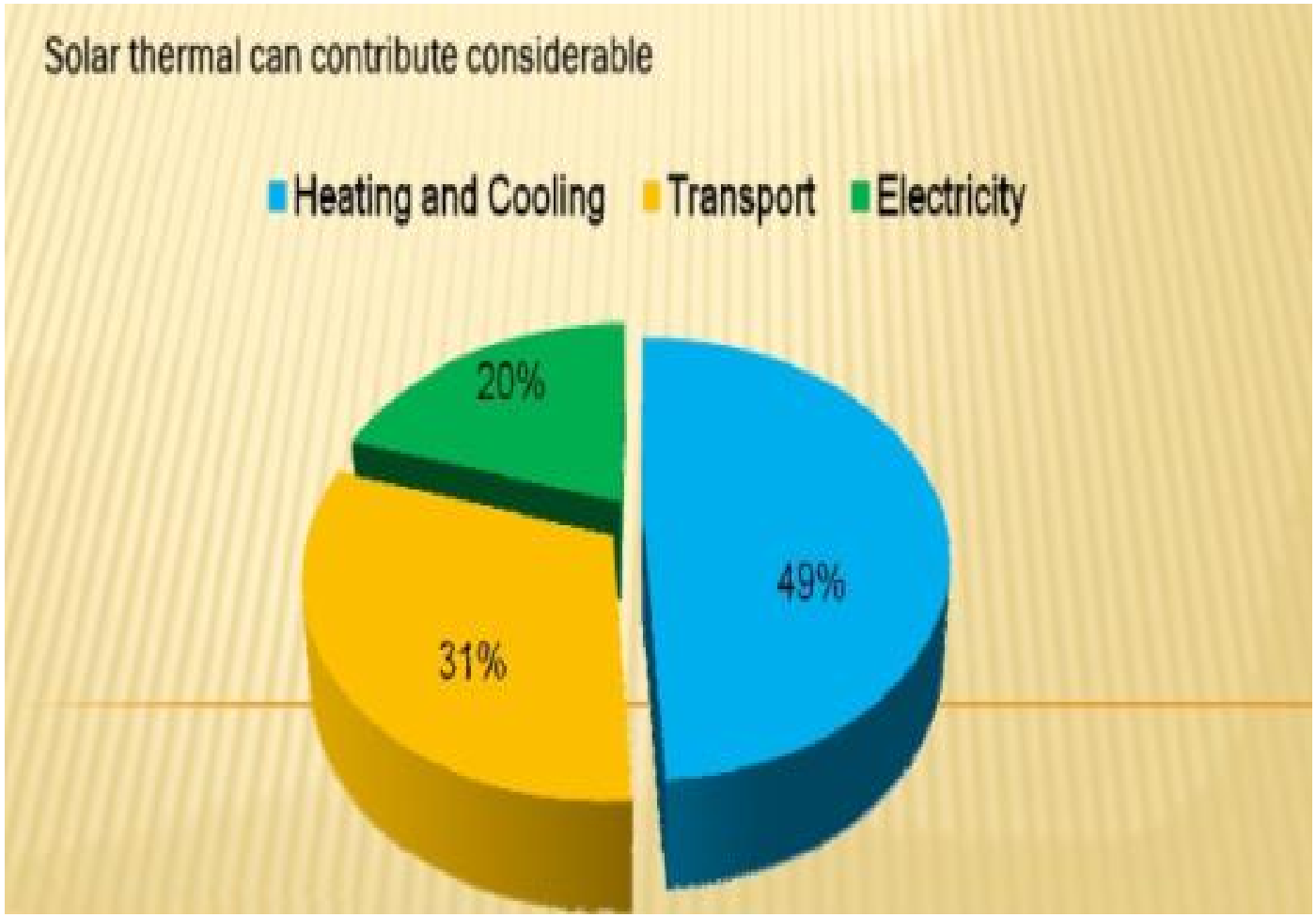
Keeping the Lights On - 2007

Source GE Solar

Keeping the Lights On - 2030

Source GE Solar

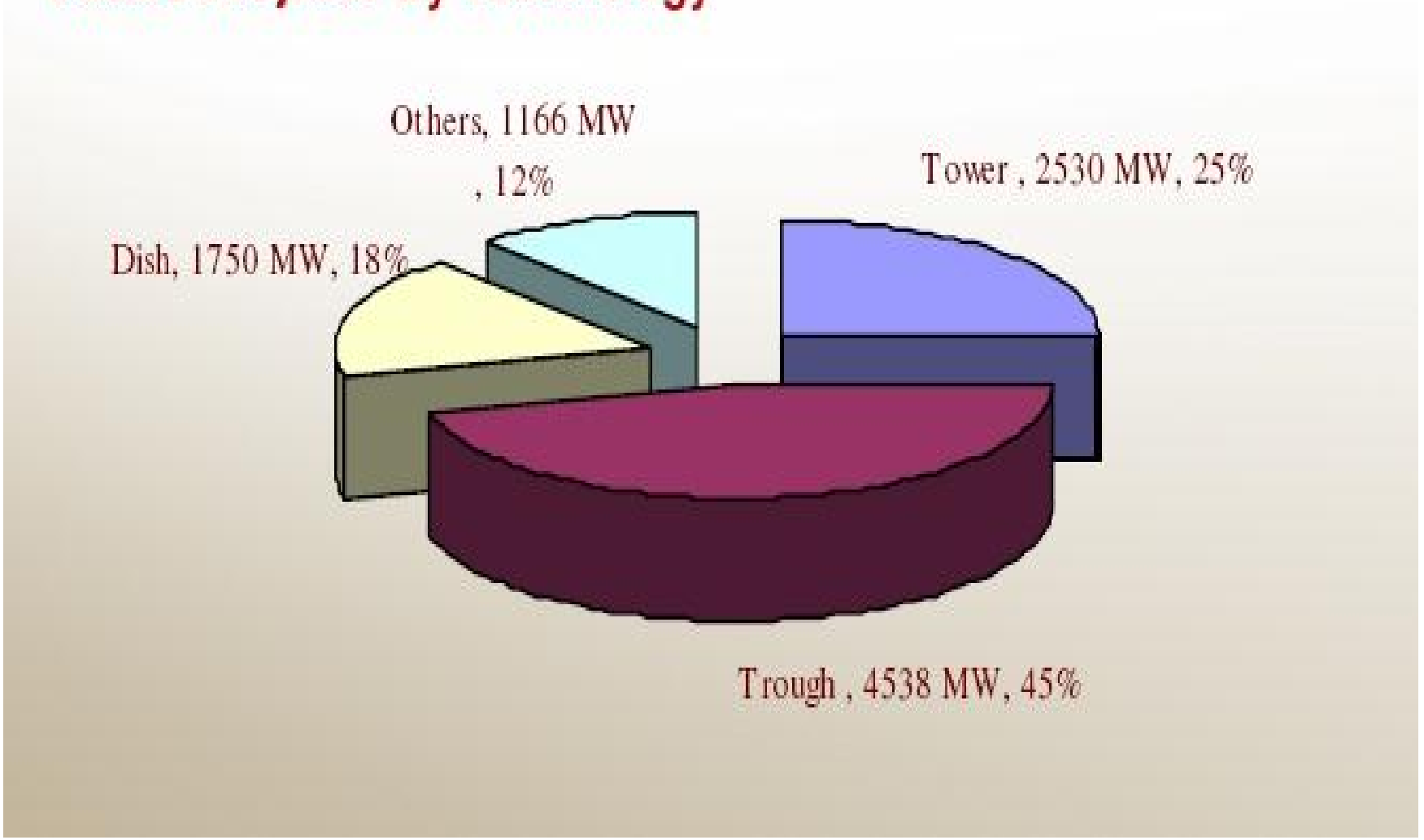
SOLAR THERMAL POWER (FUTURE)



(Source: EREC, 2006)

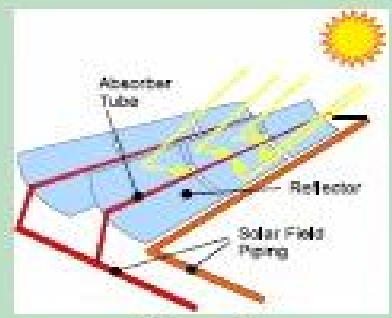
Global Trends

Future Projects-By Technology

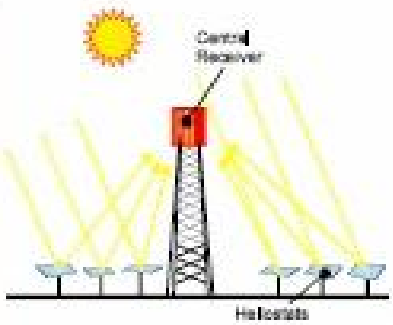


THE TECHNOLOGY

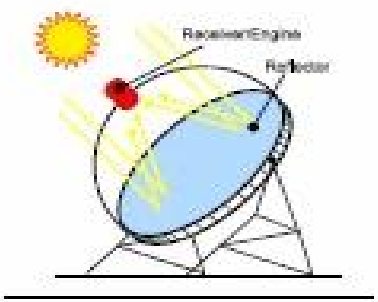
VARIOUS TYPES OF SOLAR THERMAL (CSP) TECHNOLOGY



Trough



Tower



Dish

Fresnel

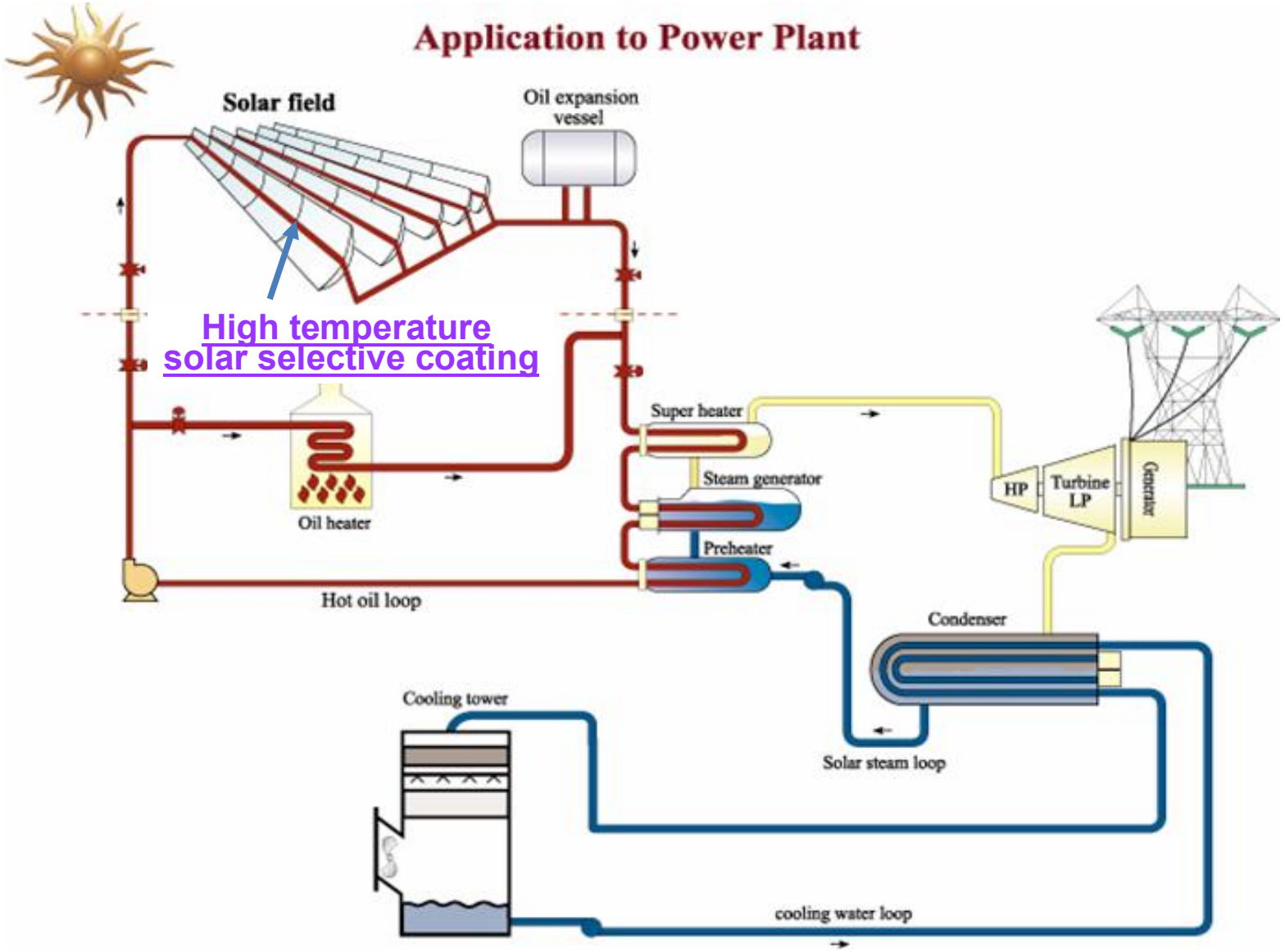
- 20 + years of operational experience worldwide
- 400+MW installed
- Established global supply chain
- Molten salt, or hot oil storage
- Indirect steam generation

- Array of individually tracking mirrors
- Less land requirement
- Small scale demo plants operating
- Molten salt storage capability
- Higher operating temp

- Distributed systems possible
- Higher temperature
- Higher cost
- Not proven at scale
- Limited storage capability
- Suitable for off-grid generation

- Lower efficiency
- Lower cost
- Unproven tech

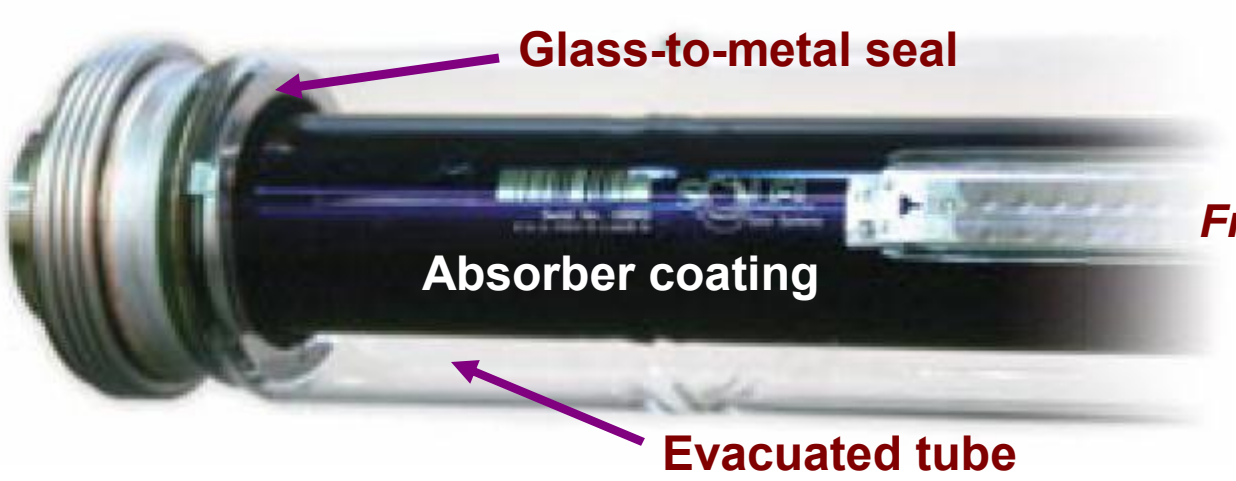
Parabolic Trough Technology for Solar Power Generation



From: Solel (USA)

Salient Features of Absorber Tubes

- Typically, a long SS tube with solar selective coating surrounded by evacuated glass tube
- Glass-to-metal seal to achieve vacuum and metal bellows to heat exchanger
- Vacuum = 10^{-4} Torr



From: Solel (USA)

Challenges:

- Glass-to-metal seal failures due to insufficient protection
- Hydrogen release related failures
- Sputtering on large tubes – Large investment & infrastructure

No Indigenous Efforts on Sputter Deposited Solar Absorber Tubes

Need for Newer Solar Absorbers for Power Generation

Concentrating Solar Power (CSP) Technologies

- **Private industries such as Space Age, Maharaja Techno Group, KG Industries, many more and BARC approached NAL for sputter deposited high temperature solar selective coatings**

Parabolic Trough

Solar Power Tower

Parabolic Dish

High Temperature Stable Solar Absorber Coatings (>400°C)

Basic Requirements of a High Temperature Solar Absorber

- High solar absorptance (>0.90)
- Low thermal emittance (<0.05, e.g., on Cu) : Radiative losses α T^4
- High thermal stability (>400°C)
- Long-term stability at higher operating temperatures
- High corrosion resistance

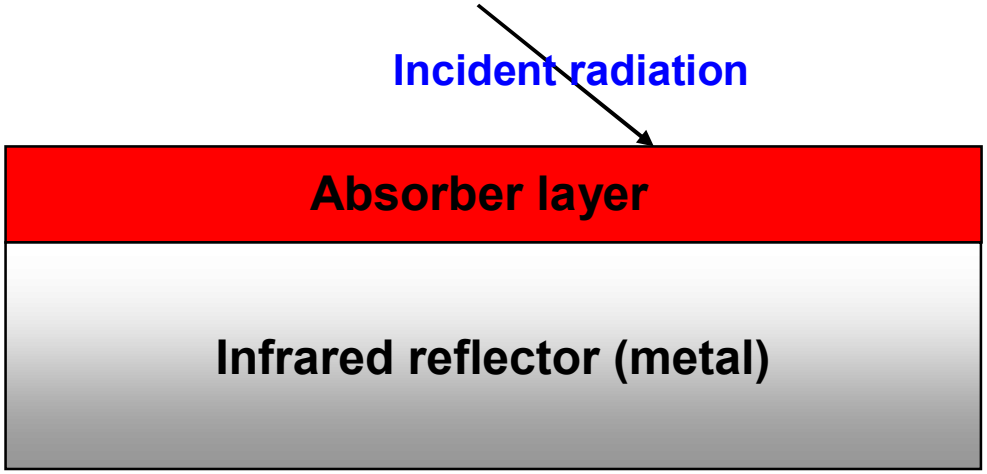
Important Cermet based High-Temperature Solar Selective Coatings

Coating	α/ε	Thermal Stability
Ni-Al_2O_3	0.94/0.06	500°C in air
Pt-Al_2O_3	0.92/0.14	600°C in H_2
Mo-Al_2O_3	0.96/0.16	500°C in vacuum
W-Al_2O_3	0.93/0.024	-
W-SiO_2	0.916/0.027	-
W-AlN	0.93/0.10	500°C in vacuum
SS-AlN	0.95/0.13	500°C in vacuum

→ Australian patent

Long Term Thermal Stability Not Known in Public Domain

ABSORBER-REFLECTOR TANDEM



It is a combination of two materials, one highly absorbing in the visible region and the other highly reflecting in the infrared.

NAL Initiatives on High Temperature Solar Selective Coatings

(Sputter Deposited Nanostructured Tandem Absorbers)

Motivation

- Technology for high temp. SSC not available in the Country

Novelty

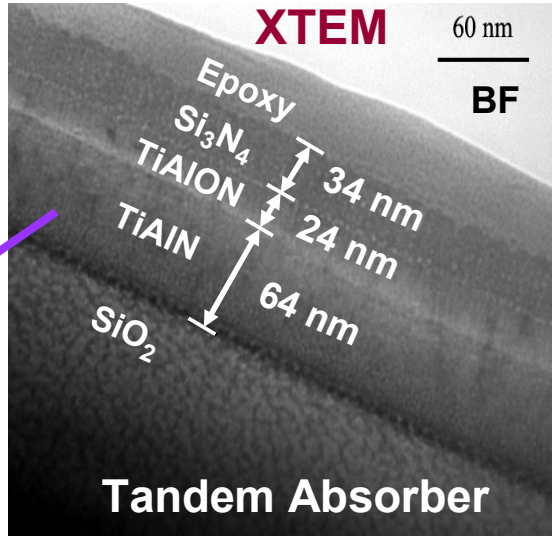
- Transition metal nitrides and oxy-nitrides
- Compositional stability at high temp.
- FIRST OF ITS KIND

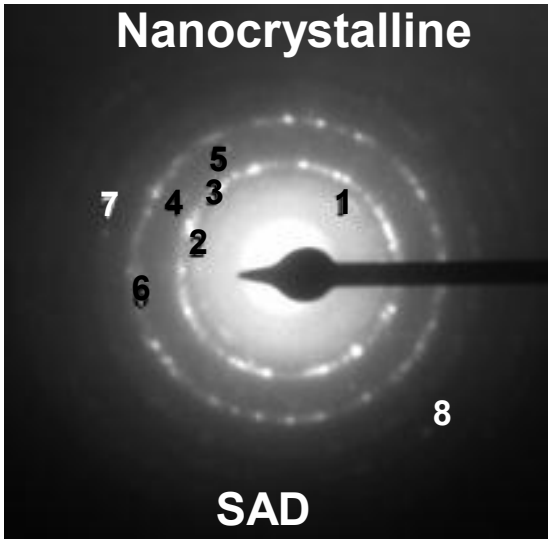
~120 nm Thickness

Coating	α/ε	Stability in air
*$TiAlN/TiAlON/Si_3N_4$	0.95/0.07	550°C
$TiAlN/CrAlON/Si_3N_4$	0.95/0.07	450°C
$NbAlN/NbAlON/Si_3N_4$	0.95/0.06	500°C
TiAlN/AlON	0.94/0.06	550°C

*Ideal Coating for Solar Power Generation

Patent filed in India, Germany & Australia - 2006



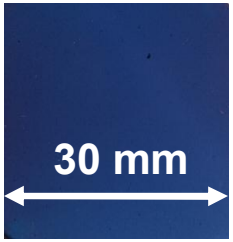


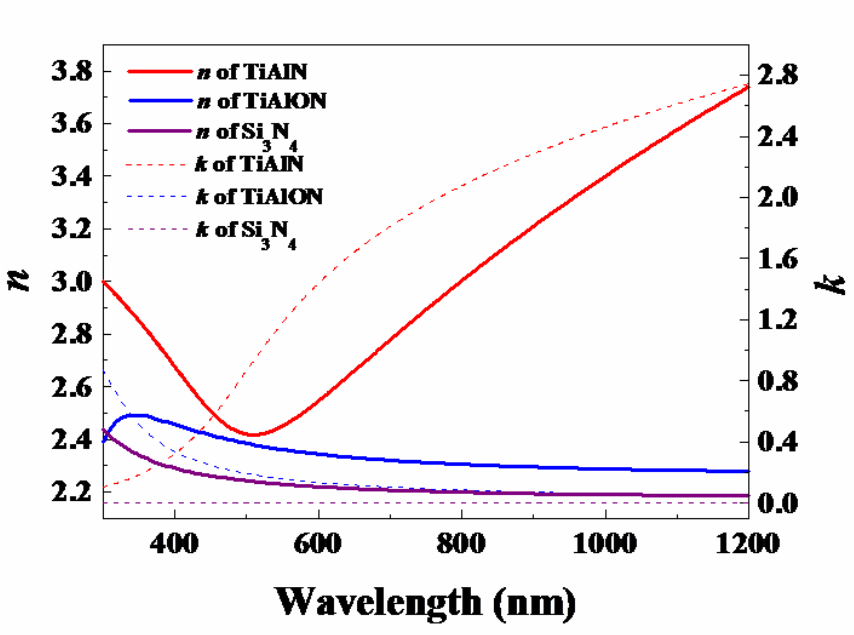
Barshilia et al. App. Phys. Lett. 89 (2006)191909

Laboratory Scale Sputter Deposited Solar Selective Coatings

Long Term Thermal Stability in Air…

- Stable up to 525°C for 50 hrs
  450°C for 150 hrs
  350°C for 225 hrs
- Stability in vacuum: 750°C for 2 hrs
- No phase transformation up to 800°C



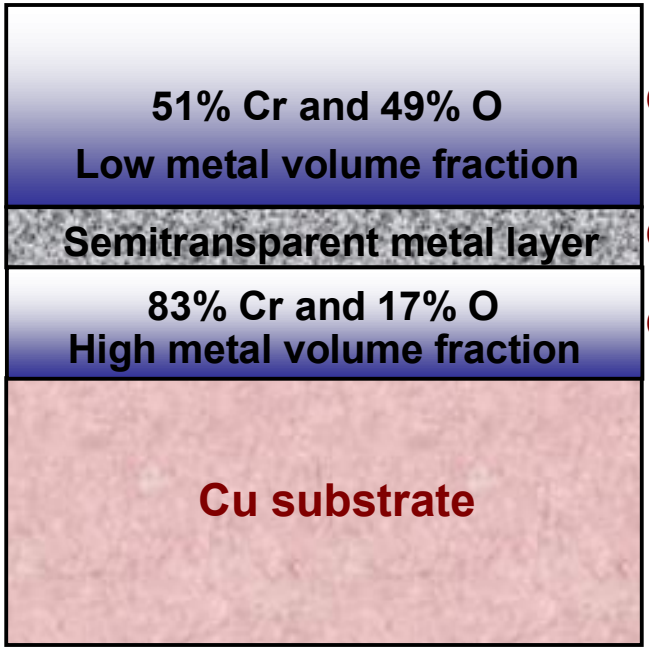


- Graded refractive indices
- TiAlN as the main absorber layer

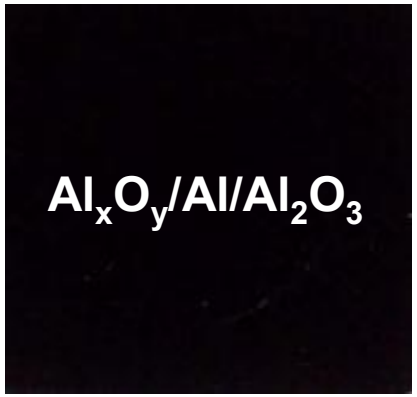
Why?

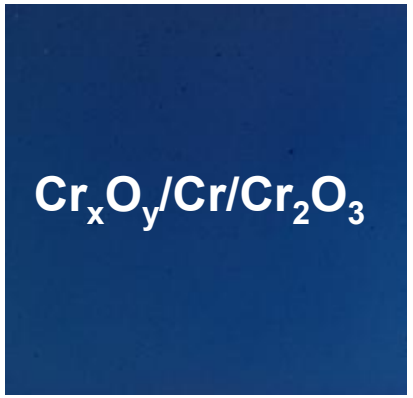
- TiAlN acts as a diffusion barrier for metal
- Interdiffusion between TiAlN/TiAlON and TiAlON/Si_3N_4 is very low up to 600°C
- TiAlN, TiAlON and Si_3N_4 exhibit very high oxidation resistance: 750, 900 & 1400ºC

Other Initiatives - Multilayer Absorbers & Nanocermets for Low- and Mid-Temperature Applications



Coating	α/ε	Stability
$Cr_xO_y/Cr/Cr_2O_3$	0.91/0.06	325°C
*$Al_xO_y/Al/Al_2O_3$	0.97/0.06	350°C
$HfO_x/Hf/HfO_2$	0.92/0.05	400°C
Ag/Al_2O_3	0.92/0.05	300°C





Salient Features:

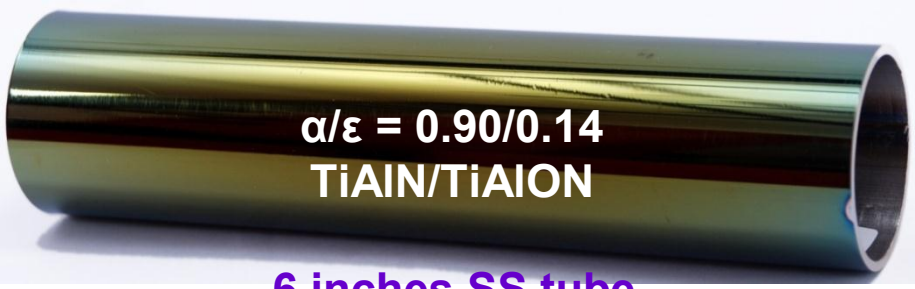
- α/ ε = 0.91/0.06
- Stable up to 325°C in air for 2 hrs and 250°C for 250 hrs
- Coating process can be scaled up for domestic hot water applications

*Green Technology : Potential Candidate for Replacement for Black Chrome

Scaling Up of The Laboratory Process for the Deposition of Nanostructured Solar Selective Coatings on 6” Long Tubes

Novelty

- A dry, clean and green process for manufacture of solar selective coating
- New coating combination
- High solar selectivity
- High thermal stability
- Long service life at higher operating temperature (*Theoretical*)



Magnetron

Supported by MNRE, New Delhi

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TANDOM ABSORBERS

Harish barshilia , V.W.Grips , K.S.Rajam

US Patent #7,585,568 B2 (2009)


you save energy
you save money
you save the
environment


New challenges
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The need to consider a new future
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New opportunities
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EcoNomics


Thank You